ANALYSIS AND DESIGN OF HAMMERHEAD BRIDGE PIER USING STRUT AND TIE METHOD.

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DEDICATION

TO MY BELOVED PARENT,
HAJI AHYAT BIN MD. NOR
AND
HAJJAH KAMSIAH BTE BERNEH

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ABSTRACT.

The main advantages of truss model are their transparency and adaptability to arbitrary geometric and loading configuration. In strut-and-tie modeling, the internal stresses are transferred through a truss mechanism. The tensile ties and compressive struts serve as truss members connected by nodal zones. The advantages have been thrust into the back ground by several recent developments of design equations based on truss models,

The present study is focus on developing a uniform design procedure for applying the strut-and-tie modeling method to hammerhead pier. A study was conducted using hammerhead piers that were previously designed using the strength method specified by code. This structure was completed and had put into service. During the inspection, cracks were observed on the piers. The scope of this study is to highlight the application of a newer generation strut-and-tie model, which is not practice at the time of the original design. Depth to span ratios varies from 1.5 to 2.11 and the girders are transferring loads very close to the support edge, making these hammerheads ideals candidates for strut-and-tie application. This study only focus on comparison the reinforcement detail drawing produce previously designed using the strength method, and reinforcing requirement using strut-and-tie model.

Based on the design studies, a well-defined procedure for designing a hammerhead pier utilizing the strut-and-tie model was established that may be used by bridge engineers.

There could be numerous reasons for the crack to develop. Shrinkage, stress concentration or some erection condition may be a few of them.

ABSTRAK.

Kelebihan model “strut and tie ” ia ketelusan melihat kerangka yang di cadangkan dan memudahkan melihat dan meramalkan kedudukan beban yang dikenakan terhadap struktur yang di cadangkan.

Analisis mengikut model “strut and tie ” mengunakan kaedah kekuatan mampatan dan kaedah kekuatan tegangan yang saling bertindak diantara satu sama lain hasil daripada ikatan disetiap nod. Kebaikan analisis mengunakan kaedah kekuatan mampatan dan kekuatan tegangan yang saling betindak diantara mereka telah membuat pengkaji cuba membangunkan kaedah rekabentuk berpandukan kaedah model “strut and tie model”.

Kajian ini menjurus untuk memajukan satu kaedah yang setara untuk merekabentuk menggunakan kaedah model “strut and tie ” untuk tiang Jambatan berbentuk T. Kajian ini dikendalikan menggunakan struktur tiang jambatan berbentuk T yang telah direkabentuk terlebih dahulu menggunakan analisa kekuatan lentur mengikut keperluan amalan rekabentuk.

Struktur ini telah siap dibina dan dibuka untuk kegunaan lalulintas. Semasa pemerhatian terhadap struktur tersebut didapati ada beberapa rekahan di permukaan dinding struktur. Bidang kajian ini adalah untuk menunjukkan penggunaan analisis model “strut and tie model” yang masih dalam peringkat pembangunan boleh diguna pakai untuk mereka bentuk struktur tersebut. Nisbah ketinggian dinding tembok dan panjang rasuk adalah berbeza diantara 1.5 hingga 2.11 dan beban yang terletak diatas rasuk tersebut, hampir dengan kedudukan tiang rasuk, ini membuatkan struktur tersebut amat sesuai untuk dianalisis mengunakan kaedah analisis model “strut and tie ”.

Hasil daripada kajian rekabentuk ini, satu kaedah rekabentuk mengunakan tindak balas struktur “strut and tie ” dapat dimajukan untuk dicadangkan untuk merekabentuk struktur tiang jambatan berbentuk T, yang mana boleh digunakan oleh Jurutera Jambatan.

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LIST OF SYMBOLS

a	=	depth of the compression block
A_s	=	the required area of steel
A_c	=	cross sectional area at the end of Strut
A_n	=	area of a Nodal Zone face in which the force is framing, measured perpendicular to the direction of the force.
b	=	width of concrete section
b_w	=	the width of web
d	=	depth from extreme compression fibres to reinforcing steel
D	=	depth of the nodal zone
D_A	=	available effective depth
D_R	=	Required effective depth
f'_c	=	concrete compressive strength.
f_{cu}	=	effective compressive strength and
f_y	=	the tie yield strength
F_i	=	force in strut or tie *i*
F_n	=	nominal strength of Strut, Tie, or Node, and
F_u	=	factored force demand of the Strut, Tie, or Node.
l_i	=	length of member *i*
M_n	=	nominal moment capacity
N_u	=	the factored tie force
P_n	=	nominal resistance of strut or tie
P_u	=	ultimate capacity of strut or tie
V_c	=	the nominal shear strength provided by the concrete
V_n	=	the factored shear force at the section considered
W	=	width of the nodal zone

β_s	=	1.00 for prismatic Struts in uncracked compression zones,
β_s	=	0.04 for Struts in tension members,
β_s	=	0.75 if Struts may be bottle shaped and crack control reinforcement is included,
β_s	=	0.60 if Struts may be bottle shaped and crack control reinforcement is not included, and
β_s	=	0.60 for all other cases.
β_n	=	1.00 if Nodes are bounded by Struts and/or bearing areas,
β_n	=	0.80 if Nodes anchor only one Tie, and
β_n	=	0.60 if Nodes anchor more than one Tie.
ϕ	=	strength reduction factor,
ε_{mi}	=	mean strain of member *i*
ρ_{vi}	=	steel ratio of the *i*-th layer of reinforcement crossing that strut
γ_i	=	angle between the axis of a strut and the bars

CHAPTER 1

INTRODUCTION

1.1 Introduction

Strut-and-tie modeling is an analysis and design tool for reinforced concrete elements in which it may be assumed that internal stresses are transferred through a truss mechanism. The tensile ties and compressive struts serve as truss members connected by nodal zones. The internal truss, idealized by the strut-and-tie model, implicitly account for the distribution of both flexure and shear.

1.2 Problem Statement

Three procedure are currently used for the design of load transferred members such as deep beams:

- Empirical design method
- Two or three dimensional analysis, either linear or nonlinear
- By mean of trusses composed of concrete struts and steel tension ties.

Strut and tie model is considered a rational and consistent basis for designing cracked reinforced concrete structure. It is mainly applied to the zones where the beam theory does not apply, such as geometrical discontinuities, loading points, deep beams and corbels.

The main advantage of truss model are their tranparency and adaptability to arbitrary geomatric and loading configuration. In strut-and-tie modelling, the internal stresses are tranferred through a truss mechanism. The tensile ties and compressive struts serve as truss members connected by nodal zones. The advantages have been thrust into the back ground by several recent developements of design equations based on truss models,

In 1998, the AASHTO LRFD Bridge Specifications (1998) incorporated the strut and tie modeling procedure for the analysis and design of deep reinforced concrete members where sectional design approaches are not valid. In most instances, hammerhead piers can be defined as deep reinforced concrete members and therefore, should be designed using the strut-and-tie modeling approach.
However, most bridge engineers do not have a broad knowledge on the strut-and-tie model due to the unfamiliarity with the design procedure. Therefore, it is likely that, with the formulation of a well-defined strut-and-tie modeling procedure, practicing engineers will become more comfortable with the design method and therefore, employ the method more often and consistently.

The succesful application of a strut-and-tie model depend on a reliable visualization of the path of the force flows. In a typical strut-and-tie analysis, the force distribution is visualised as compressive struts and tensiles ties, respectively.

1.3 Objectives

The specific objectives of the study are:

- ❖ To ascertain the degree of strut-and-tie modeling implementation.
- ❖ To compare the flexure and shear reinforcing requirements for typical hammerhead type bridge piers using both strut-and-tie modeling and standard sectional design practices, and
- ❖ To develop a uniform design procedure for employing strut-and-tie modeling for hammerhead piers.

Most codes of practice use sectional methods for designed of conventional beams under bending and shear. ACI building Code 318M-95 assumes that flexure and shear can be handle separately for the worst combination of flexure and shear at a given section. The interaction between flexure and shear is addressed indirectly by detailing rules for flexural reinforcement cutoff point.

1.4 Scope of Study

In these study pier caps was designed using the strut-and-tie modeling procedure and the results compared to the results of the sectional design method. By comparing the results, the reduction or increase in the flexural steel and the shear steel can be quantified.

These new procedure can provide rational and safe design framework for structural concrete under combined actions, including the effects of axial load, bending and torsion.

In addition specific checks on the level of concrete stresses in the member are introduced to ensure sufficient ductile behavior and control of diagonal crack widths at service load level.

no one has undertaken the task of developing a consistent approach to the design of hammerhead pier caps employing the strut-and-tie modeling method.

The specific objectives of the study are to compare the reinforcing requirements of the strength design method AASHTO LRFD [12] for flexure and shear design with the strut-and-tie modeling method and to develop a procedure for modeling a hammerhead pier cap that can be applied by practicing engineers. This work presents a clear and concise procedure for utilizing the strut-and-tie model for the analysis and design of hammerhead piers. As was stated in section 4.3, an increase in tensile reinforcing was incurred by the AASHTO LRFD [12] strut-and-tie procedure.

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